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RESEARCH MEMORANDUM

THE EFFECT OF SWEEPBACK ON THE LONGITUDINAL CHARACTERISTICS AT A MACH NUMBER OF 1.24 OF A $\frac{1}{30}$-SCALE SEMISPAN MODEL OF THE BELL X-5 AIRPLANE FROM TESTS BY THE NACA WING-FLOW METHOD

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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RESEARCH MEMORANDUM

THE EFFECT OF SWEEPBACK ON THE LONGITUDINAL CHARACTERISTICS AT A MACH NUMBER OF 1.24 OF A $\frac{1}{30}$-SCALE SEMISPAN MODEL OF THE BELL X-5 AIRPLANE FROM TESTS BY THE NACA WING-FLOW METHOD

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SUMMARY

Tests were made at a Mach number of 1.24 by the NACA wing-flow method to determine the effect of sweepback on the longitudinal characteristics of a $\frac{1}{30}$-scale semispan model of the Bell X-5 airplane with wings in the 40° and 50° sweptback positions and with a tail incidence of -6°. The characteristics of the fuselage alone were also determined. Lift, drag, and pitching moments were obtained for various angles of attack at a Mach number of 1.24. The Reynolds numbers of the tests were 1×10^6 ±5 percent and 0.85×10^6 ±6 percent based on the mean aerodynamic chords of the 50° and 40° wings, respectively. A comparison is made with the results of a previous test of the model with a 60° sweptback wing and tail incidence of -6°.

The results of the tests of the model (when considered as a variable-sweep configuration) indicated that as the sweepback angle was increased from 40° to 50°, the drag coefficient was reduced about 0.01 at zero lift. With further increase in sweepback to 60°, the reduction in drag coefficient was 40 percent of that obtained between 40° to 50°. The 60° configuration had the lowest drag up to a lift coefficient of nearly 0.5. At higher lift coefficients, the 50° configuration at first and finally the 40° configuration had the lowest drag. The rearward movement of neutral point obtained by increasing the sweepback angle from 40° to 60° (together with a small translation of the wing of about 3 percent M.A.C.) varied from about 9 to 18 percent mean aerodynamic chord, depending on lift coefficient. The variation

of lift-curve slope $dC_L/d\alpha$ decreased linearly with increase in sweepback angle from a value of 0.072 at 40° to a value of 0.058 at 60°.

INTRODUCTION

As part of a program to determine the aerodynamic characteristics of the proposed Bell X-5 airplane incorporating a wing the angle of sweep of which can be varied in flight, an investigation is being made at low supersonic speeds by the NACA wing-flow method on a $\frac{1}{30}$-scale semispan model. Results of tests to determine the longitudinal characteristics of this model with the wing swept back 60° have been reported in reference 1. For the present tests measurements were made of normal force, chord force, and pitching moment of the semispan model for a tail incidence of -6° with the wing swept back 50° and 40° referred to the 25-percent-chord line. Similar measurements were also made of the fuselage alone. The effective Mach number over the wings of the model for the tests was about 1.24 and the Reynolds number was of the order of 1×10^6.

In the interest of making these data available as soon as possible, they are presented with only a limited analysis.

SYMBOLS

V velocity, feet per second

ρ mass density, slugs per cubic foot

q effective dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$

S model wing area, semispan (includes area in fuselage between perpendiculars from wing-fuselage intersection to plane of symmetry), square feet

α angle of attack of fuselage, degrees

Λ sweepback angle referred to 25-percent-chord line, degrees

L lift force (resultant force perpendicular to stream velocity), pounds

D	drag force (resultant force parallel to stream velocity), pounds
M	pitching moment, inch-pounds
C_L	lift coefficient $\left(L/qS\right)$
C_D	drag coefficient $\left(D/qS\right)$
C_m	pitching-moment coefficient $\left(M/qS\bar{c}\right)$
$\bar{c}$	mean aerodynamic chord of wing, based on the relationship $\dfrac{\int_0^{b/2} c^2 dy}{\int_0^{b/2} c\, dy}$ where b is wing span, c is local chord, and y is spanwise coordinate, inches
$\bar{c}_t$	mean aerodynamic chord of tail, inches
M_L	local Mach number over wing surface of F-51D airplane
M_w	effective Mach number over wing of model
M_t	effective Mach number over tail of model
i_t	tail incidence, degrees
R	Reynolds number based on mean aerodynamic chord $\bar{c}$
$dC_L/d\alpha$	variation of lift with angle of attack, per degree
dC_m/dC_L	variation of pitching moment with lift $\dfrac{dC_m/d\alpha}{dC_L/d\alpha}$

Prime indicates coefficients based on dimensions of configuration with 60° sweptback wing.

APPARATUS AND TESTS

The tests were made by the NACA wing-flow method in which the model is mounted in the region of high-speed flow over the wing of an F-51D airplane. The contour of the airplane wing in the test region for the present investigation was designed to give a uniform velocity field at Mach numbers near 1.25 at a flight Mach number of about 0.71.

The configurations tested and reported herein consisted of the $\frac{1}{30}$-scale semispan model of the Bell X-5 airplane equipped successively with wings of 40° and 50° sweepback angles referred to the 25-percent-chord line. For the present investigation, the horizontal tail incidence was -6°. A test was also made for the fuselage alone.

A photograph of the semispan model equipped with end plate is shown in figure 1; photographs of the model equipped with wings swept back 40° and 50° are shown in figures 2 and 3, respectively. The geometric characteristics of the model, wings, and horizontal tail surface are given in table I; other details of the model are shown in figure 4. The fuselage of the model was constructed of mahogany, whereas dural was used for the wings and tail surfaces. A duct was included in the fuselage to simulate to some extent the air intake and flow through the jet engine of the full-scale airplane. The airfoil section perpendicular to the unswept 38-percent-chord line (through wing pivot point of the full-scale airplane) is an NACA $64_{(10)}$A011 at the root (through pivot point) and tapers to NACA $64_{(08)}$A008.6 at the tip. The horizontal tail has an NACA 64A006 airfoil section parallel to the air stream and is swept back 45° along the 25-percent-chord line. The aspect ratios of the 50° and 40° wings are, respectively, 2.98 and 3.77, considering the F-51D airplane wing as a reflection plane. The semispan model, curved to conform to the curvature of the wing in the test region, was mounted close to the airplane wing surface, and the shank of the model, which passed through a slot in the wing, was attached to a balance.

The model and balance were arranged to oscillate as a unit, and the balance measured the forces both normal and parallel to the center-line thrust of the model at all angles of attack. For each test, continuous measurements were made of angle of attack, normal force, chord force, and pitching moment as the model was continuously oscillated through an angle-of-attack range of -4° to 16° for the 50° wing configuration and -4° to 12° for the 40° wing configuration. The average rate of oscillation of the model was about 27° per second which corresponds to a rate of rotation of approximately 1° per 80 chord lengths of motion with respect to the air stream. This rate of rotation is believed to be sufficiently small to preclude any appreciable inertia effects.

The model was originally designed and constructed so that the pitching moment would be measured about the 25-percent mean-aerodynamic-chord position (gross weight center-of-gravity location of the full-scale airplane) of the wing in each sweep position. However, with subsequent changes in wing span and fillets, the positions about which the pitching moments were measured actually correspond to the 29-percent and the 35-percent mean aerodynamic chords of the 50° and 40° wings, respectively.

A typical chordwise Mach number distribution in the test region on the airplane wing as determined from static-pressure measurements at the wing surface with the model removed is indicated in figure 5. From static-pressure measurements made with a static-pressure tube located at various distances above the surface of the test section, the vertical Mach number gradient was found to be 0.009 per inch up to a distance of 6 inches above the surface. The effective dynamic pressure at the model wing q, the effective Mach number over the model wing M_w, and the effective Mach number over the model tail M_t were determined from an integration of the Mach number distribution over the area covered by the wing and tail of the model, respectively. For the chordwise Mach number distribution shown in figure 5, the value of M_w for both the 50° and 40° wings was between 1.23 and 1.24 and M_t was the same. A more complete discussion of the method of determining the Mach number and dynamic pressure at the model can be found in reference 2.

The tests were made in high-speed dives of the F-51D airplane. The Reynolds numbers were 1×10^{6} ±5 percent based on $\bar{c}$ of the 50° wing and 0.85×10^{6} ±6 percent based on $\bar{c}$ of the 40° wing.

RESULTS AND DISCUSSION

The aerodynamic characteristics are presented in figure 6 for the model with the 40° sweptback wing, in figure 7 for the model with the 50° wing, and in figure 8 for the fuselage alone. The coefficients of the 40° and 50° sweptback-wing configurations are based on their respective wing dimensions; the coefficients for the fuselage alone are based on the dimensions of the 60° wing of reference 1. Data are shown for both increasing and decreasing angles of attack. Pitching-moment data were obtained only over part of the angle-of-attack range for the 50° wing because of limitations in the capacity of the pitching-moment element of the balance.

The curves of figures 6 and 7 have been replotted for comparison in figure 9. Also shown in figure 9 for comparison are the aerodynamic characteristics of the model with the wing in the 60° sweptback position (reference 1). (Note: Dimensions of 60° wing are included in table I of this paper for convenient reference.) The pitching-moment-coefficient curves in figure 9 have all been converted to the 25-percent mean-aerodynamic-chord point of each wing. The 25-percent mean aerodynamic chord is the location of the gross weight center of gravity of the full-scale airplane. The 25-percent mean-aerodynamic-chord locations of each wing correspond to different locations on the fuselage. (See fig. 4.)

In order to indicate the variation in characteristics with sweep, as for a variable-sweep airplane, lift, drag, and pitching-moment coefficients for the 40°, 50°, and 60° configurations, all based on the dimensions of the 60° wing, are presented in figure 10. The pitching-moment coefficients in figure 10 refer to the 26-percent mean aerodynamic chord of the 60° wing. It should be noted that the wing of the model translates approximately 3 percent mean aerodynamic chord as the sweep of the wing of the model is increased from 40° to 60°.

The effect of angle of sweepback Λ on the drag coefficient at various lift coefficients, on the rate of change of pitching-moment coefficient with lift coefficient $dC'_{m_{0.26\bar{c}}}/dC'_L$ for the lift coefficients of 0, 0.2, and 0.4, and on the rate of change of lift coefficient with angle of attack $dC'_L/d\alpha$ at zero lift are shown in figure 11. The curves are obtained from the data of figure 10, and the following discussion is based on figures 10 and 11.

Drag.- The values of drag presented are considered qualitative because they include the drag of the end plate and are subject to an unknown effect of the semispan configuration on the drag of the fuselage. However, the variation of drag coefficient with lift coefficient (see reference 1) and the differences between drag coefficients for the different configurations are believed to be unaffected by these factors. As the sweepback angle of the wing was increased from 40° to 50°, the drag coefficient at zero lift of the semispan model decreased from about 0.09 to 0.08, a reduction of 0.01. With further increase in sweepback to 60°, the zero-lift drag coefficient of the semispan model was further reduced to about 0.076, a decrement of only about 0.004. The drag-coefficient reduction obtained by increasing the sweepback angle from 50° to 60° was about 40 percent as much as that obtained by increasing the sweepback from 40° to 50°. The drag coefficient at zero lift of the fuselage alone was about 0.06 (fig. 10). Deducting this value from the drag coefficient of the complete model gave the drag coefficient of the wing and tail, plus wing-fuselage and tail-fuselage interference. This difference (hereinafter called wing-tail drag coefficient) had a value of about 0.016 for the 60° configuration and about 0.030 for the 40° configuration. It is thus seen that increasing the sweepback angle from 40° to 60° reduced the wing-tail drag coefficient at zero lift by about 47 percent. The 60° swept-wing configuration had the lowest drag up to a lift coefficient of nearly 0.5 at which the drag of all configurations was the same. At higher lift coefficients, the lowest drag was obtained at first with the 50° configuration and finally for the 40° configuration.

<u>Neutral point</u>.- The position of the neutral point, shown in figure 11 for lift coefficients of 0, 0.2, and 0.4 moved rearward from about 9 to 18 percent mean aerodynamic chord (depending on lift coefficient) as the sweepback angle was increased from 40° to 60°. The most forward location of the neutral point $(C_L = 0)$ was at 45 percent mean aerodynamic chord (40° wing) and the maximum rearward location was at 69 percent mean aerodynamic chord $(60° \text{ wing}, C_L = 0.4)$.

<u>Lift-curve slope</u>.- The variation of lift-curve slope $dC_L'/d\alpha$ at zero lift decreased linearly with increase in sweepback angle from a value of 0.072 at 40° to a value of 0.058 at 60°.

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REFERENCES

1. Silsby, Norman S., Morris, Garland J., and Kennedy, Robert M.: Longitudinal Characteristics at Mach Number of 1.24 of a $\frac{1}{30}$-Scale Semispan Model of Bell X-5 Variable-Sweep Airplane with Wing Swept Back 60° from Tests by NACA Wing-Flow Method. NACA RM L50E02a, 1950.

2. Johnson, Harold I.: Measurements of Aerodynamic Characteristics of a 35° Sweptback NACA 65-009 Airfoil Model with $\frac{1}{4}$-Chord Plain Flap by the NACA Wing-Flow Method. NACA RM L7F13, 1947.

TABLE I

GEOMETRIC CHARACTERISTICS OF $\frac{1}{30}$ - SCALE SEMISPAN MODEL

OF BELL X-5 VARIABLE-SWEEP AIRPLANE

Wing dimensions:			
Section (root) perpendicular to unswept 38.58-percent-chord line of wing	NACA $64_{(10)}$A011		
Section (tip) perpendicular to unswept 38.58-percent-chord line of wing	NACA $64_{(08)}$A008.6		
Sweepback angle, deg	40	50	60
Semispan, in.	5.31	4.60	3.88
Mean aerodynamic chord, in.	3.10	3.20	3.64
Chord at tip, in.	1.84	1.84	1.84
Chord at plane of symmetry, in.	4.40	4.50	4.25
Area (semispan), sq in.	14.97	14.20	13.79
Aspect ratio	3.77	2.98	2.18
Dihedral (chordal plane), deg	0	0	0
Incidence (chordal plane), deg	0	0	0

Horizontal tail:	
Section	NACA 64A006
Semispan, in.	1.91
Mean aerodynamic chord, in.	1.43
Chord at tip, in.	0.72
Chord at plane of symmetry, in.	1.95
Area (semispan) sq in.	2.55
Aspect ratio	2.86
Height (above wing chord), in.	0.56
Length from $0.26\bar{c}$ of 60° swept wing to $0.25\bar{c}_t$, in.; from $0.29\bar{c}$ of 50° swept wing to $0.25\bar{c}_t$, in.; from $0.35\bar{c}$ of 40° swept wing to $0.25\bar{c}_t$, in.	6.83

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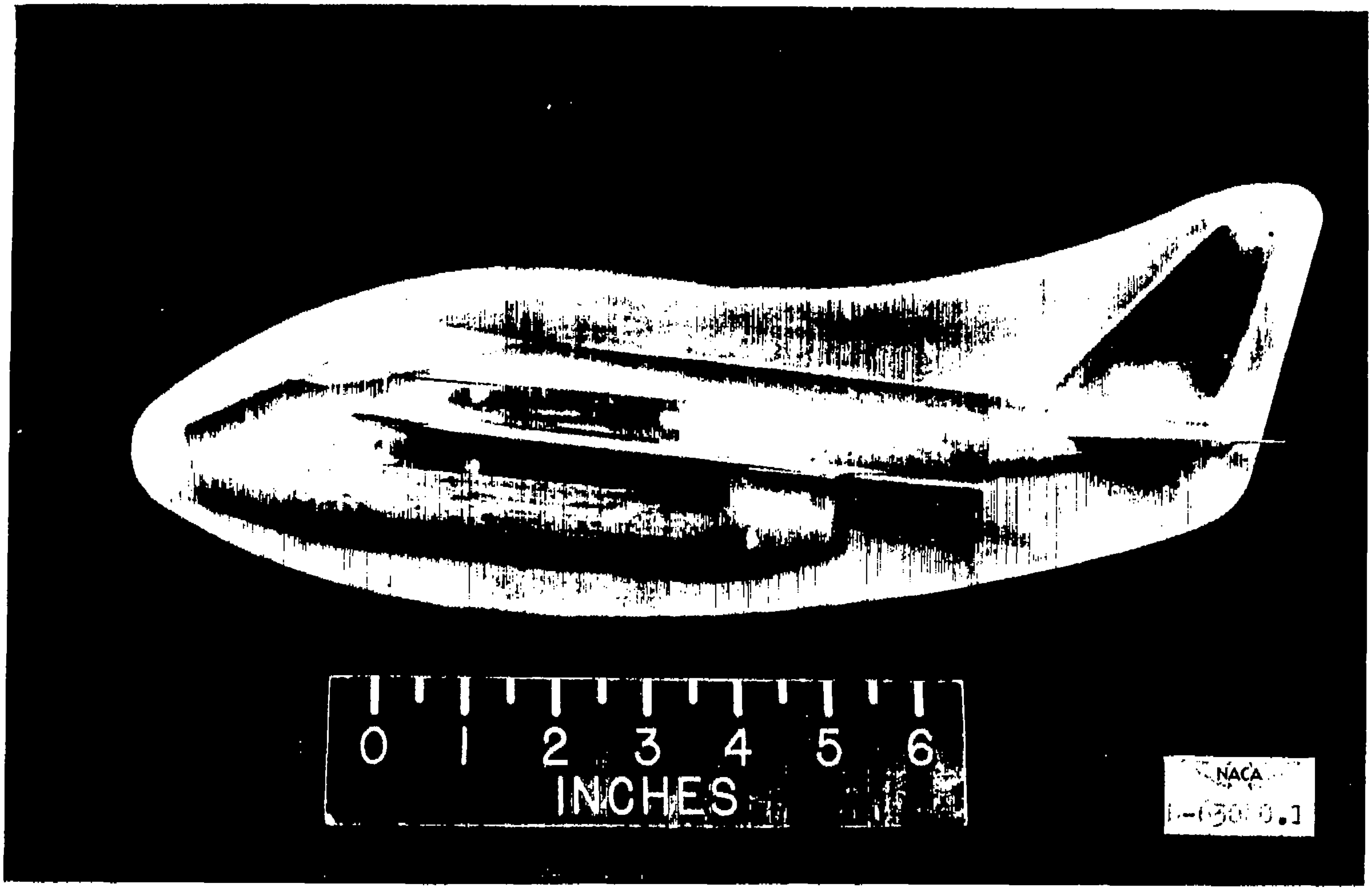


Figure 1.- Side view of semispan wing-flow model of the Bell X-5 airplane.

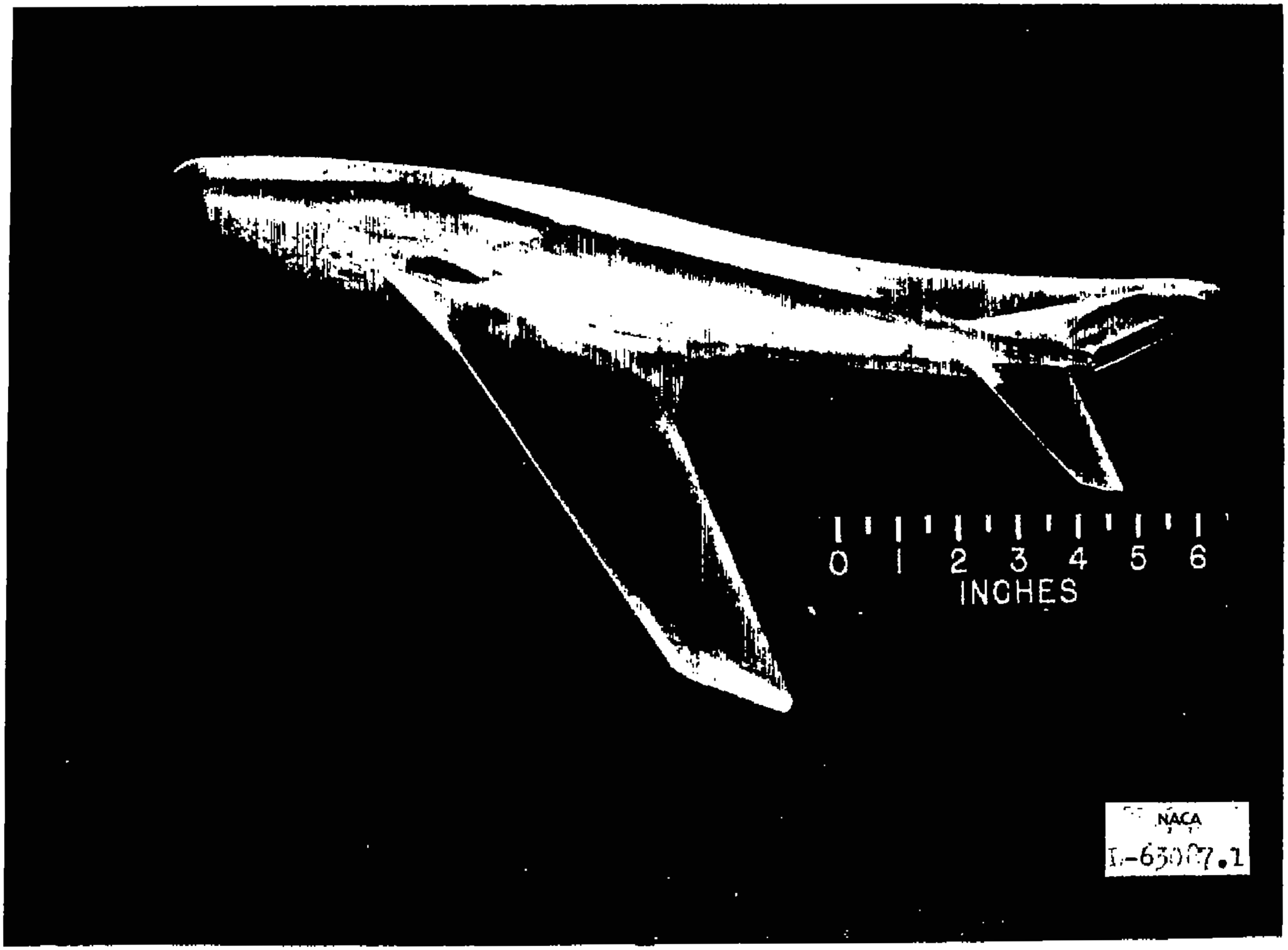


Figure 2.- Semispan wing-flow model of the Bell X-5 airplane with wing in 40° sweep position.

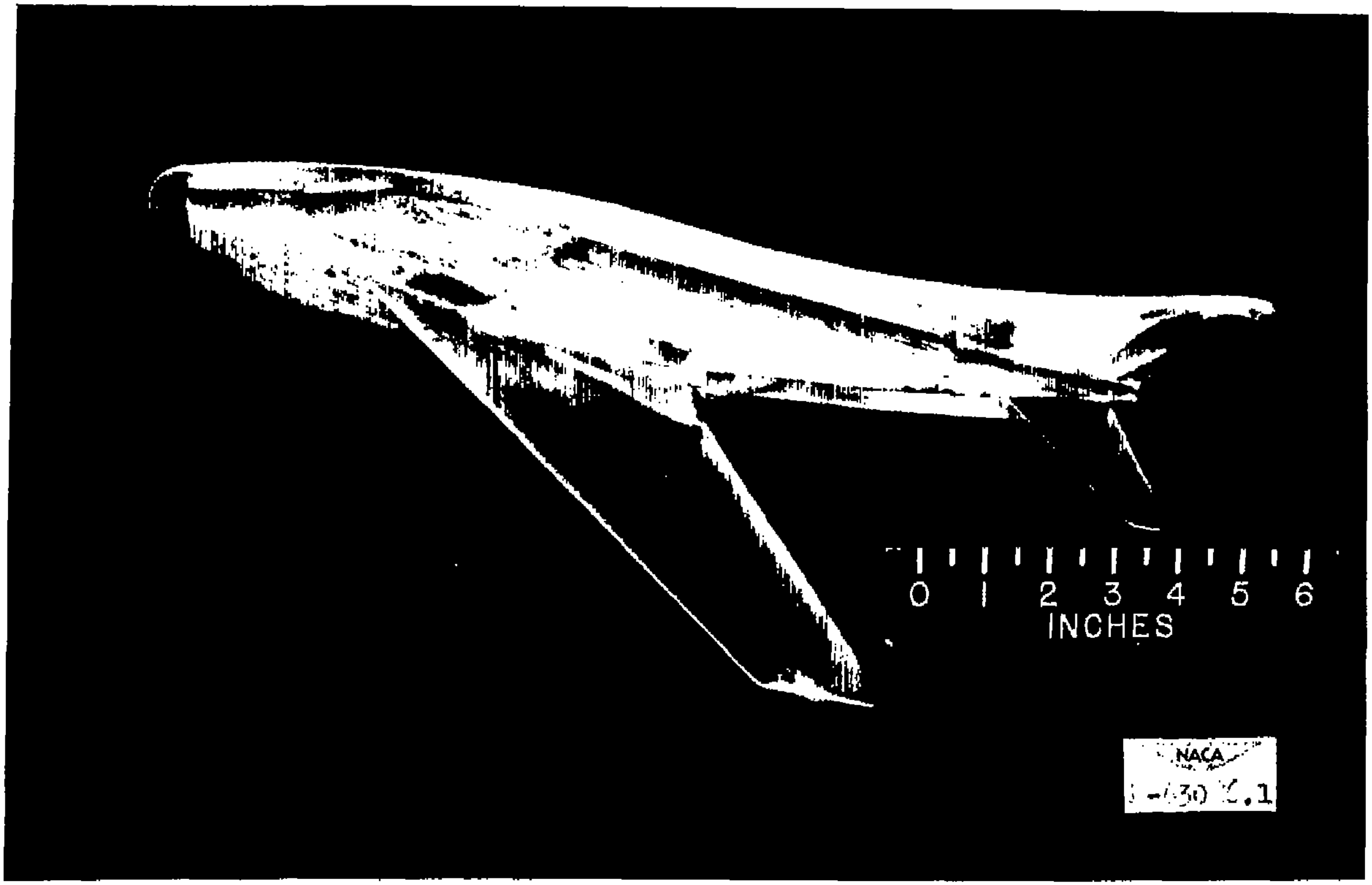
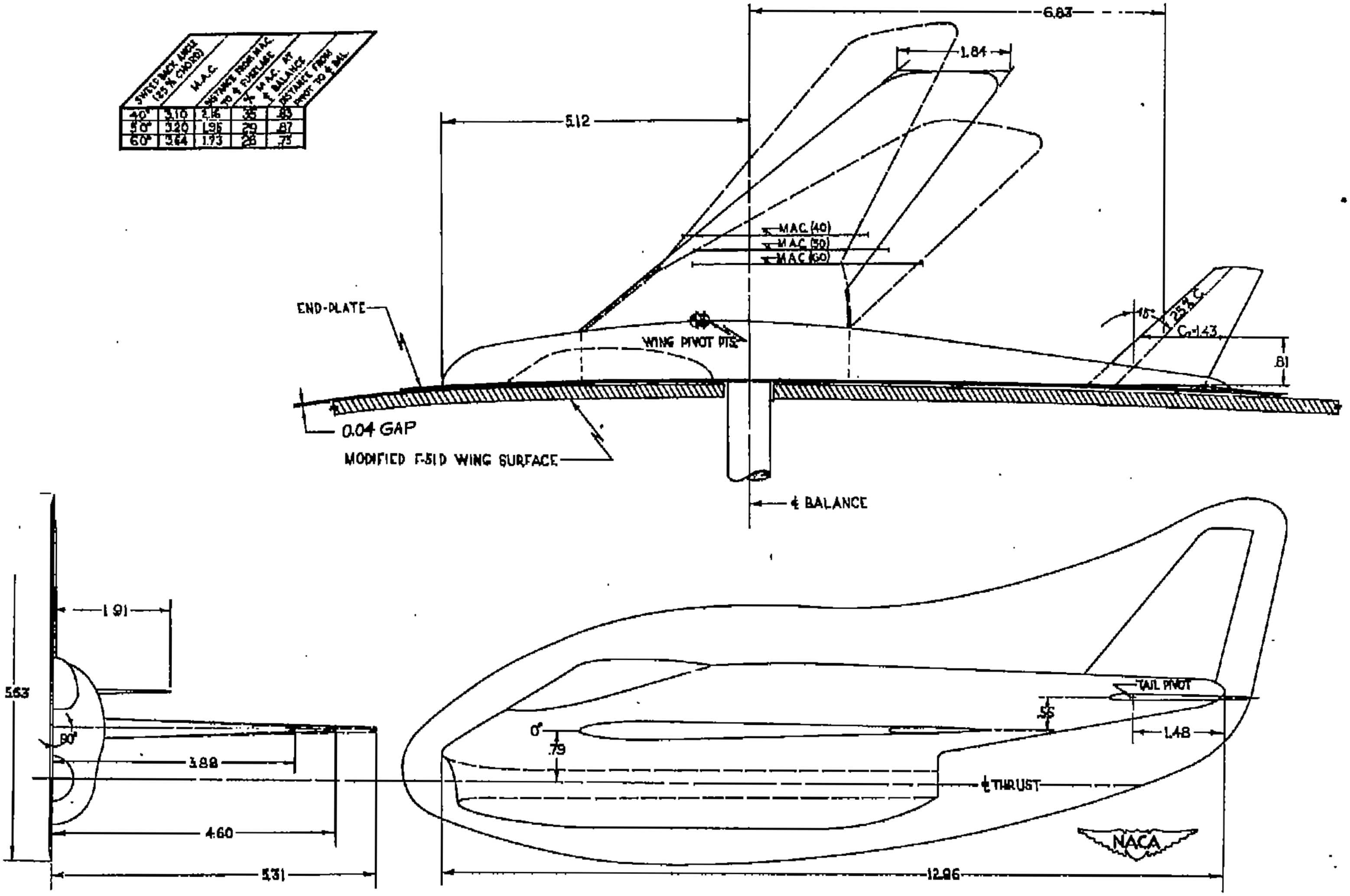


Figure 3.- Semispan wing-flow model of the Bell X-5 airplane with wing in 50° sweep position.



SWEEPBACK ANGLE (25% CHORD)	M.A.C.	DISTANCE FROM M.A.C. TO ℄ FUSELAGE	% M.A.C. AT ℄ BALANCE	DISTANCE FROM PIVOT TO ℄ BAL.
40°	3.10	2.16	.35	.83
50°	3.20	1.96	.29	.87
60°	3.64	1.73	.28	.75

Figure 4.- Details of the semispan model of the Bell X-5 airplane with wing in 40°, 50°, and 60° sweep position. (All dimensions in inches.)

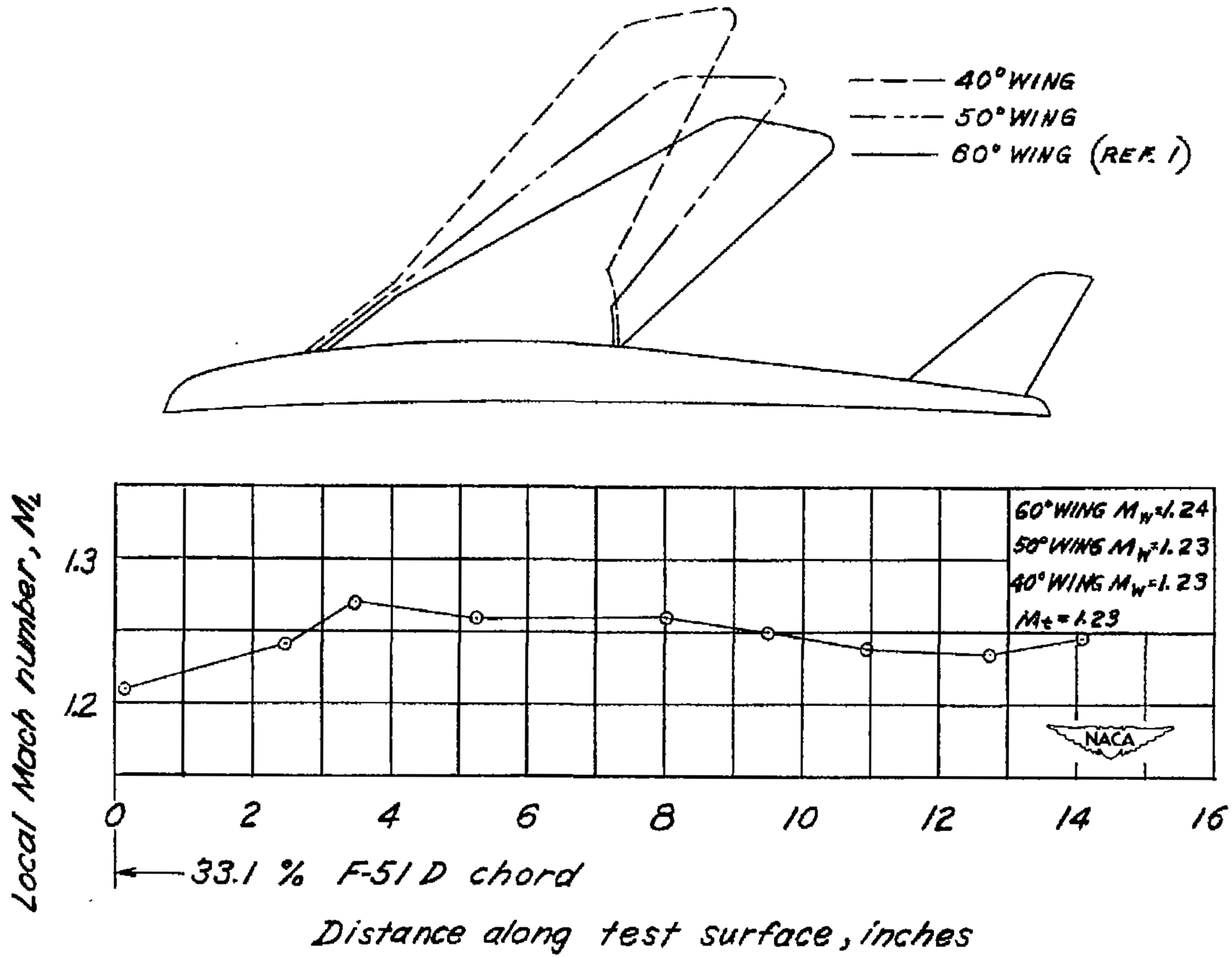


Figure 5.- Typical chordwise distribution of Mach number along the surface of test section. Chordwise location of model also shown.

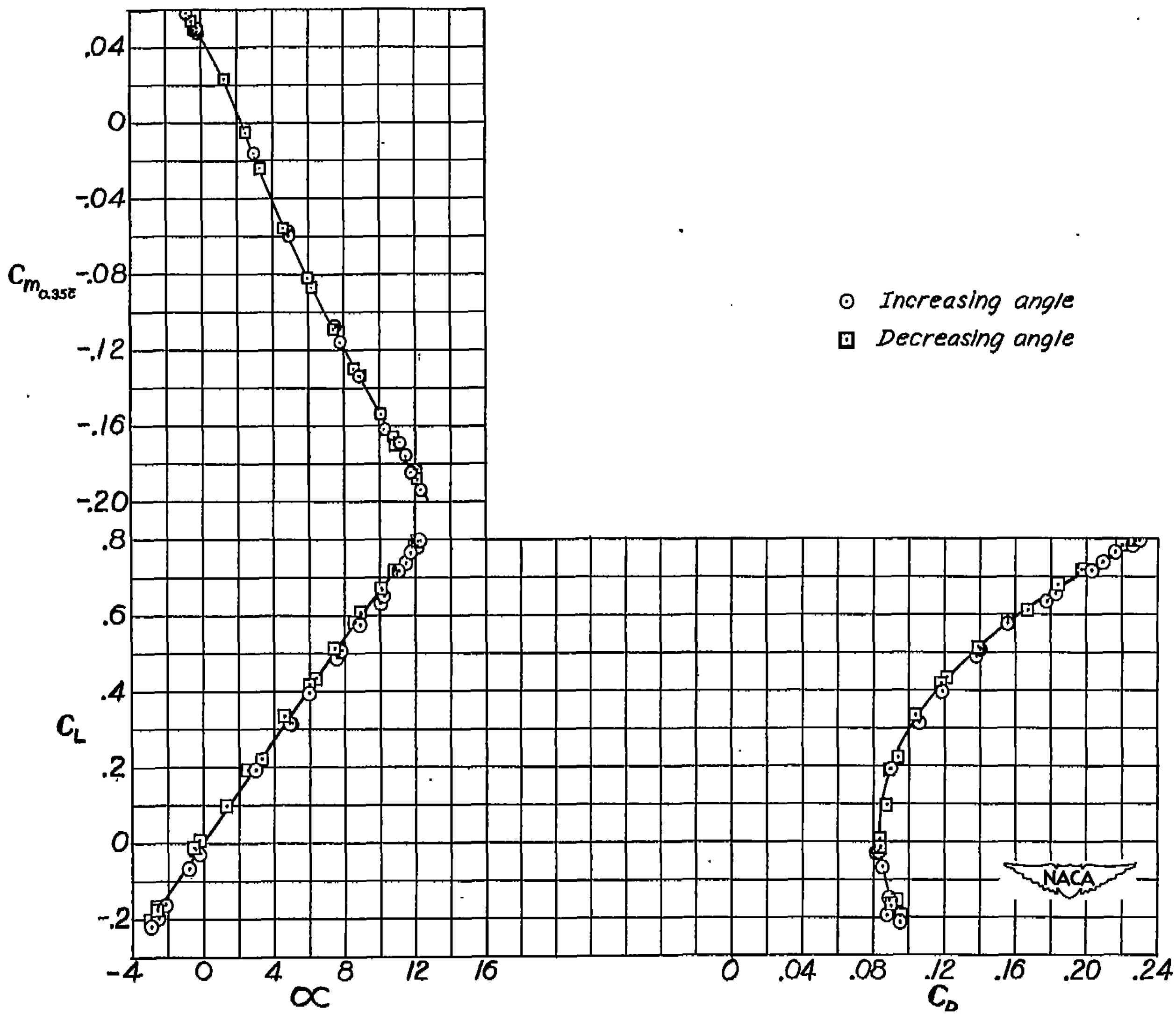


Figure 6.- Aerodynamic characteristics of semispan model of the Bell X-5 airplane. Sweepback angle 40°; $i_t = -6°$; $M_W = 1.23$.

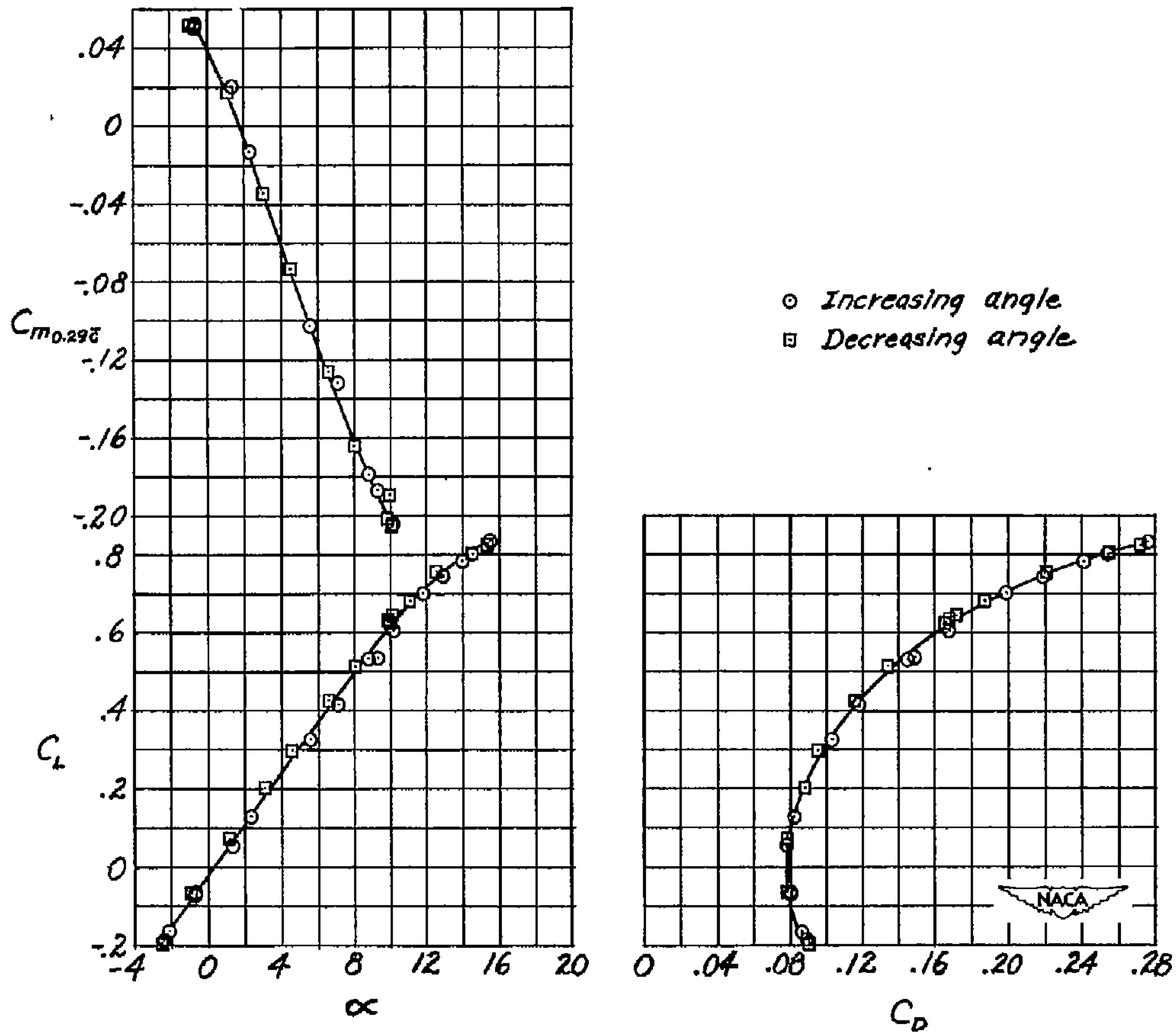


Figure 7.- Aerodynamic characteristics of semispan model of the Bell X-5 airplane. Sweepback angle 50°; $i_t = -6°$; $M_W = 1.23$.

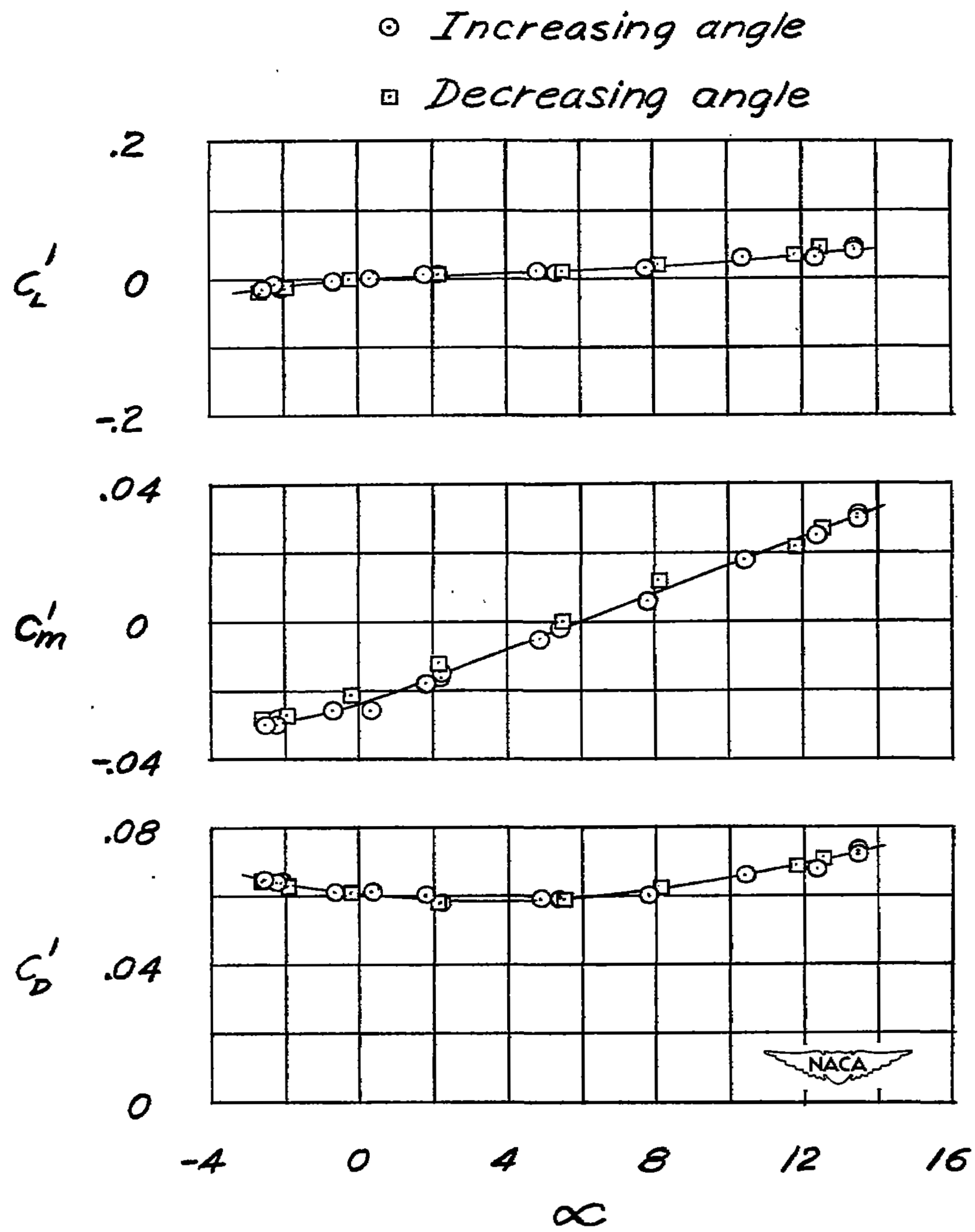


Figure 8.- Aerodynamic characteristics of semispan model of fuselage of the Bell X-5 airplane. $M_W = 1.23$ (coefficients based on 60° wing dimensions).

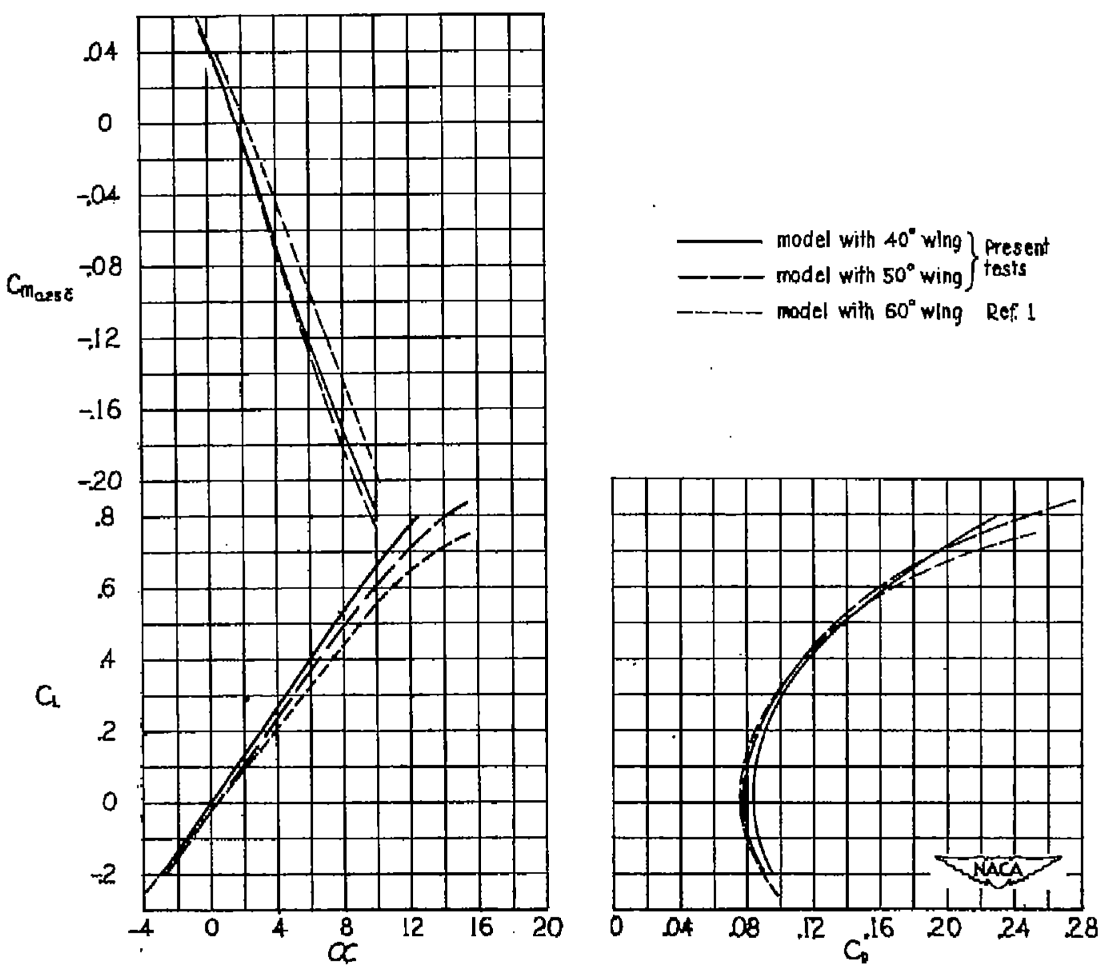


Figure 9.- Comparison of aerodynamic characteristics of semispan model of the Bell X-5 airplane with wing in 40° and 50° sweptback positions. Characteristics of model with wing in 60° position (reference 1) also shown; $i_t = -6^{\circ}$; $M_W = 1.23$. (Coefficients are based on dimensions of respective wings.)

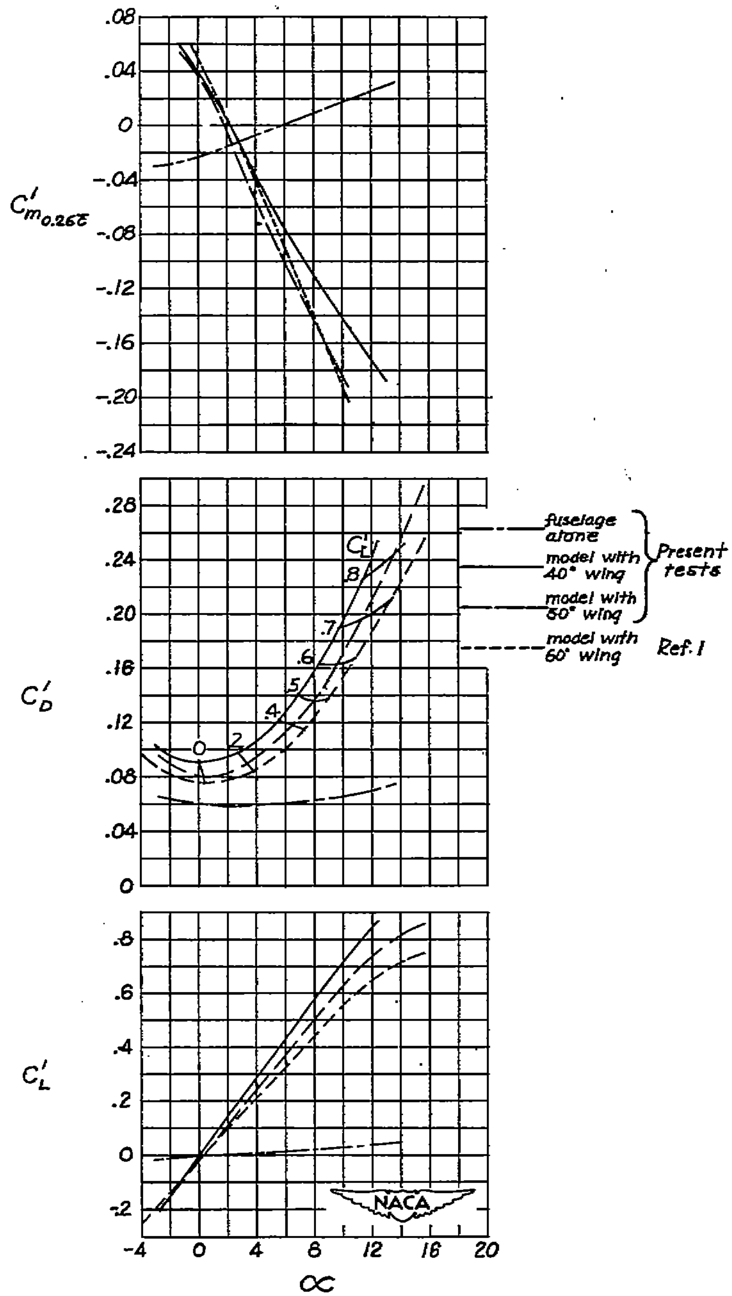


Figure 10.- Comparison of aerodynamic characteristics of semispan model of the Bell X-5 airplane with wing in 40°, 50°, and 60° sweptback positions. $i_t = -6^\circ$; $M_W = 1.23$. Characteristics of fuselage alone also shown. (All coefficients based on dimensions of 60° wing.)

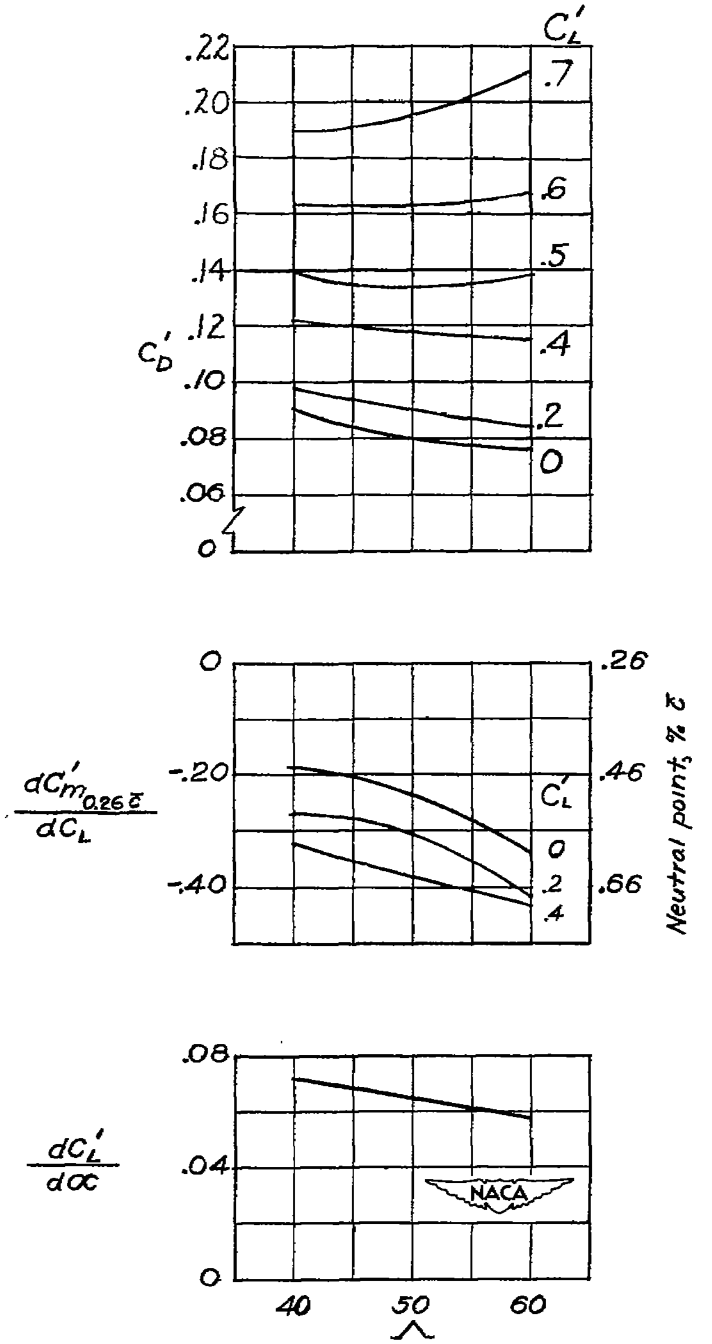


Figure 11.- Effect of sweepback angle on the drag coefficient at various lift coefficients, on the rate of change of pitching-moment coefficient with lift coefficient and on the rate of change of lift coefficient with angle of attack for the semispan model of the Bell X-5 airplane. $i_t = -6^\circ$; $M_W = 1.23$. (All coefficients based on dimensions of the 60° wing.)

NACA-Langley - 11-27-50 - 275